LOWER CACHE CREEK, YOLO COUNTY, CA
CITY OF WOODLAND AND VICINITY

DRAFT FEASIBILITY REPORT
FOR POTENTIAL FLOOD DAMAGE
REDUCTION PROJECT

APPENDIX I

Qualitative Geomorphologic and Channel Stability Assessment of Lower Cache Creek

Final Report

Qualitative Geomorphic and Channel Stability Assessment of Lower Cache Creek

Date: September 12, 2001

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1.0 INTRODUCTION

The objective of this reconnaissance level study is to assist Camp Dresser & McKee (CDM) and the Sacramento District Corps of Engineers (Corps) in identifying key geomorphic processes affecting channel morphology and river dynamics of Lower Cache Creek from Road 94-B to the Yolo Settling Basin. A qualitative review of past reporting and obvious channel stability and sediment transport conditions found in the Lower Cache Creek study reach was conducted during a three week period using readily available data and information gathered during a site inspection of the project reach. Hydraulic model results from the CDM/MBK HEC-RAS model were used to bracket hydraulic characteristics for a range of flows and to perform a qualitative review of channel dynamics. Model results from the Cache Creek Settling Basin FLO-2D model were used to qualitatively estimate changes in the settling basin performance and trap efficiency for baseline conditions and the Flood Barrier Alternative. Settling Basin modeling results for the Setback Levee Alternative were not available at the time of reporting. Findings from the review of available information were used to:

- Estimate existing channel stability;
- Estimate existing O&M requirements;
- Assess the stability and maintenance requirements of the Setback Levee Alternative;
- Assess impacts of the Flood Barrier and Setback Levee Alternatives to flow and sediment transport to the Settling Basin and its sediment trap efficiency;
- Assess the need for a training levee or modifications to the proposed training levee in the Settling Basin;
- Determine the need for additional information or future studies in order to complete the project design.

1.1 Data Collection

Information for this investigation was obtained from CDM, the U.S. Army Corps of Engineers the Corps, MBK Engineers, the California State Division of Mines & Geology, and NHC archives. A list of historical aerial photographs used for this project is shown in Table 1, and a list of historical topographic maps is shown in Table 2. Key documents, plans, and other materials collected for this study are listed in the References section. An on-site field inspection of the project area was conducted in August, 2001 by nhc.

2.0 GEOMORPHOLOGY

2.1 Background

Located north of the City of Woodland, the project area consists of the downstream 12.1 miles of Cache Creek, referred to as Lower Cache Creek (Figure 1). The project area begins at station 780+00, about 2 miles downstream of County Road 94B, and extends downstream (easterly) to station 140+00 in the Cache Creek Settling Basin. Originally constructed in 1937, the settling basin has been modified several times to increase flood capacity and to provide sediment storage. The primary function of the settling basin is to preserve the flow conveyance capacity of the

Yolo Bypass by trapping Cache Creek sediments in the settling basin rather than allowing them to enter the bypass (Corps, 2001).

Six bridges cross the creek in the project area, the I-5 bridge complex at station 582+00, SR 113 at station 415+00, and CR 102 at station 292+00. The I-5 bridge complex consists of 4 bridges, northbound and southbound lanes of I-5, CR 99W, and a railroad bridge. Earthen levees border Cache Creek from the settling basin to I-5. Upstream of I-5, a levee extends along the north bank whereas the south bank is higher in elevation and unleveed. Levees have existed along this reach of Cache Creek for many decades. In 1943, existing levees along Lower Cache Creek were improved from Yolo to the creek mouth to accommodate a maximum design flow of 20,000 cfs. The north side levees along Lower Cache Creek were upgraded in 1961 to convey 30,000 cfs (Corps, 2001).

Prior to 1996, Cache Creek was a major source of construction grade aggregate within the State of California (EIP, 1995). In 1996, instream aggregate mining was banned on Cache Creek as part of a stream restoration plan to protect stream habitat, groundwater, and infrastructure. During the gravel mining era, average annual gravel extraction volumes greatly exceeded estimates of inflowing gravel. Current estimates indicate that it would take several hundred years for Cache Creek to replace the volume of gravel removed as a result of aggregate mining (EIP, 1995).

2.2 Geology

Lower Cache Creek flows on alluvial fan and floodplain deposits ranging from clay and silt to coarse sand and gravel (Wahler Associates, 1982). Borehole data show clay deposits to be common at depths in excess of 20 ft to 25 ft from the ground surface, whereas more recently deposited silt and sand characterize sediments above the 20 ft to 25 ft depth (Corps, 1958; Wahler Associates, 1982).

Several faults are located in the vicinity of the project area. The Dunnigan Hills Fault is less than 5 miles northwest of the project area and is considered active due to recent activity during the Holocene epoch (the last 10,000 years) (Toppozada et al., 2000). Other faults in the region include the Zamora Fault and the Capay Fault, both of which are considered to be inactive (Jennings et al., 1994).

Lower Cache Creek has experienced a small amount of land subsidence due to ground water withdrawal. A maximum of 2.25 ft of cumulative land subsidence is estimated in the City of Woodland from 1942 to 1987.

2.3 Existing Conditions within the Lower Cache Creek Project Area

Lower Cache Creek exhibits several geomorphically distinct reaches along its length. The most significant reach change occurs near station 670+00, located 1.7 miles upstream of I-5. Upstream of station 670+00 Cache Creek was historically mined for aggregate whereas areas downstream were not. As a result, channel morphology is vastly different between these two sections of the project area. These and other geomorphic changes can be used to subdivide the creek into 6 distinct reaches (Figure 1). Key hydraulic characteristics of each reach for the 2-year flow and 100-year flow are shown in Table 3. Key geomorphic characteristics of each reach are discussed below.

Reach 1 (station 260+00 to station 140+00) is 12,000 ft in length, Cache Creek flows south in an artificially constructed channel that directs Cache Creek flows into the settling basin. The artificial channel exhibits a regular, trapezoidal cross-section with little or no change in flow capacity along its length. Dense vegetation cover throughout this reach greatly restricted the observation of in-channel features during the field inspection. As a result, in-channel features were assessed primarily from year 2000 aerial photographs which showed no apparent bank erosion sites in Reach 1.

Reach 2 (station 415+00 to station 260+00) is 15,500 ft in length and located between SR 113 and Reach 1. Reach 2 downstream of SR 113 was not visited during the site inspection due to a locked gate. From air photographs, bank vegetation in Reach 2 varied from forest cover with dense understory to open areas of tall grass extending to the water's edge. Channel banks in Reach 2 appeared stable and no areas of significant bank erosion were observed. However, some small, isolated areas of stream bank erosion were identified in the reach, such as near station 377+00. In addition, vertical scarps of exposed bank sediments approximately 3 ft high were also observed near the top of bank in the upstream part of the reach. These breaks in bank slope indicate possible slump failures along the bank, although no indications of active or excessive erosion along the toe of these banks were evident at any of these locations.

Three meander bends are located in the upstream part of Reach 2. Rock bank protection was observed at the edge of water in some parts of these meander bends, such as at station 378+00, indicating that these areas had once been eroding and were later stabilized.

Examination of Table 3 shows that Reach 2 is wider than Reaches 3 and 4 for both the 2-year and 100-year flows. Sections of Reach 2 upstream of County Road 102 exhibit broad, open areas of floodplain between the levees whereas Reaches 3 and 4 exhibit little or no floodplain surfaces and tend to become increasingly more narrow and confined with distance upstream.

Reach 3 (station 480+00 to station 415+00) is 6,500 ft in length and forms a transitional reach between the wider Reach 2 downstream and the narrower Reach 4 upstream. The downstream 1,500 feet of Reach 3 exhibits a fairly consistent line of trees along the south bank, probably planted there several decades ago. These trees occupy the lower part of the stream bank near the water's edge, indicating that little or no bank erosion has occurred here over the last several decades. Other areas of Reach 3, particularly along the north bank, are largely devoid of tree cover and instead exhibit grass and shrub covered bank slopes.

Reach 3 is significantly narrower and more entrenched than Reach 2, resulting in higher, steeper channel banks that are more prone to bank erosion and instability. In contrast to Reach 2, significant areas of bank erosion and instability are evident in several locations in Reach 3. These areas are typically characterized by eroded, vertical stream banks, slump failures, and single or multiple vertical scarps (2 ft to 3 ft high) at varying levels on the bank slope, indicating slumping of the downslope segment of bank.

Reach 4 (station 580+00 to station 480+00) is 10,000 ft in length. Trees line much of the south bank of Reach 4 whereas the north bank is virtually devoid of tree cover. Dense shrubs and grasses typically line both banks in this reach.

The frequency of bank erosion and bank instability is greater in Reach 4 than in Reach 3. Reach 4 exhibits the narrowest channel cross-section in the project area and is deeper and more entrenched than Reach 3 (Table 3). Both factors contribute to the higher incidence of bank erosion in this reach. Similar to Reach 3, 2 ft to 3 ft high vertical scarps occur at varying elevations in several parts of the stream bank (both low and high), indicating probable areas of bank slumping. A large bank erosion site is located at station 542+00 on the north bank. The erosion site is very near the levee road and will be repaired by the California State Department of Water Resources. A tight meander bend at station 502+00 also exhibits a large bank failure on the inner bank. A grade control structure constructed of sac-crete is located in the channel at station 557+00.

The frequency and magnitude of instream bar features also increases in this reach relative to Reach 3. Well-developed instream gravel bars cause the low flow channel to migrate from one side of the creek bed to the other.

Reach 5 (station 670+00 to station 580+00) is 9,000 ft in length and characterized by large meander bends that exhibit severe bank erosion along high (30+ ft) vertical banks over hundreds of lineal feet. This morphology results in the most severe and extensive bank erosion in the project area. In general, the low flow channel in this reach is much narrower than in downstream reaches, due to lower water depths and confinement of the low flow channel by large gravel bars that occupy much of the channel bed. A borrow area is located at station 602+00, separated from the creek by a high, narrow ridge of material left in place between the creek and borrow area.

A widening trend in channel morphology begins in this reach and continues with distance upstream toward Reach 6 where historical gravel mining has greatly increased channel width and depth from pre-mining levels.

Reach 6 (station 670+00 to station 780+00) is 11,000 ft long and located in a historically gravel-mined section of the project reach. This reach is very broad in comparison with the rest of the project area and is characterized by large gravel bars, areas with little vegetation that were mined as recently as the mid-1990's, and undisturbed areas of dense vegetation. Vegetation is gradually returning to denuded portions of the creek following the cessation of instream gravel mining operations in 1996.

2.4 General Comments

The following general comments regarding the geomorphic characteristics of the project area can be made from the reach descriptions listed above:

- In general, the frequency and severity of bank erosion and bank instability in the project area increases with distance upstream from Reach 1 to Reach 5.

- Channel width generally decreases with distance upstream from Reach 1 to the I-5 bridge (Reach 5). Conversely, channel depth increases with distance upstream from Reach 1 to the I-5 bridge. In other words, Cache Creek exhibits a narrower, more entrenched channel cross-section with distance upstream from the settling basin to I-5 bridge. This results in channel banks that are generally higher, steeper, and more prone to bank erosion and instability with distance upstream.
- Cache Creek exhibits a widening trend with distance upstream from I-5 bridge, due to active meander bend migration in Reach 5 and channel widening caused by gravel mining in Reach 6.
- Bank instability in the project area is characterized primarily by areas of active bank erosion and by bank slumping. Areas of active bank erosion typically exhibit nearly vertical banks of exposed sediment, indicative of recent erosion. Blank slumping is evidenced by single or multiple vertical scarps (2ft to 3 ft high) at varying levels on the bank slope, indicating slumping and subsequent erosion of the downslope segment of the bank.
- Historically, numerous bank protection works have been constructed in the project area, primarily in river bends. Thus, bank stability in these areas is due to artificial bank protection rather than inherent stream stability. Future maintenance of existing and construction of new bank protection works will be necessary in the project area, even for without-project conditions.

3.0 CHANNEL STABILITY

3.1 Longitudinal Profiles

Longitudinal profiles of Lower Cache Creek from 1955 and 2000 are compared in Figure 2 (Corps, 1958; Ayres, 2000). Examination of Figure 2 shows a clear lowering of the channel invert elevation over time, due to multiple factors including the excavation of gravel from Cache Creek, channel confinement by bridges and levees, and other factors. The amount of channel bed lowering in Figure 2 decreases with distance downstream. At the I-5 bridge, the channel invert shows a lowering of about 16 ft from 1955 to 2000 whereas only 4 ft of channel invert lowering is observed at station 270+00. Data from 1905 to 1994 at I-5 bridge show that as much as 26 ft of invert lowering has occurred here (EIP Associates, 1995). Given that channel banks at I-5 are approximately 30 ft to 35 ft in height, the historical channel was probably about 10 feet deep and much wider than it is today. Thus, channel confinement, the effects of increased flows and more than 50 years of aggregate extraction in the project reach has resulted in severe channel lowering over the last 100 years.

In addition to significant channel degradation from 1955 to 2000, Figure 2 also shows much greater channel bed variability in the 1955 invert versus the 2000 invert. This is likely due to differences in survey methods. The 1955 invert is based on ground surveys whereas the 2000 invert is extrapolated from aerially derived, GPS-based topography of the water surface. Thus, the 2000 invert profile represents estimated rather than actual measured values of the invert and lacks the bedform variability shown in 1955 survey data.

The 2000 survey also shows an unusual convex shape in the long profile from station 580+00 to station 420+00 in Figure 2. The reason for this is unclear although a grade control structure at

557+00 probably contributes to the unusually gradual stream gradient (0.00015) from station 580+00 to station 557+00 in Figure 2.

In contrast, stream gradient is about 10 times this amount in the reach immediately upstream of I-5 (station 582+00 to station 840+00), the steepest section of the project area. Stream gradient generally decreases with distance downstream of station 480+00 from about 0.0011 from station 480+00 to station 41+200 to 0.00011 from station 287+00 to station 140+00.

3.2 Historical Planform Shift

Prior to significant gravel mining, Cache Creek is described as being a wide, relatively steep braided channel upstream of Yolo and a narrow, incised channel flowing in fine-grained overbank deposits and Tule marsh downstream of Yolo (EIP Associates, 1995). In general, average channel width in gravel mined reaches of Cache Creek has decreased from this historic condition due to bridge and levee construction and aggregate extraction. Conversely, average channel depths have increased as a result of channel degradation and confinement by levees and bridges.

Readily available historical mapping and aerial photographs (Tables 1 and 2) were collected and examined to identify key changes in channel planform in the project area over time. Examination of historical aerial photographs from 1937-38, 1952, 1964, and 2000 show significant planform changes in the project area over this period. The most significant planform change from 1937-38 to 2000 is the diversion of the downstream end of Cache Creek into an artificial channel flowing south into the settling basin. In 1937-38 aerial photographs, the downstream end of Cache Creek flows east and spreads out in a series of distributary channels. By 1952, the creek is confined into a single artificial channel that flows south and terminates near the south end of the settling basin. By 2000, this artificial channel has been relocated slightly westward but retains its southerly alignment into the settling basin.

Upstream of the settling basin, historical aerial photographs from 1937-38 show Lower Cache Creek to have been in much the same alignment that it is today. Other than in the settling basin, no major changes in channel alignment are observed in the project area. There are, however, some key differences in channel appearance between 1937-38 and 2000. First, the active channel appears wider in 1937-38 aerial photographs when compared to 2000. In particular, from station 330+00 to station 260+00 the 1937-38 aerial photographs show the low flow channel meandering between large alternating gravel bars. In contrast, 2000 aerial photographs show a much narrower active channel bed with very few bar surfaces.

Visual examination of aerial photographs also showed an apparent decline in the amount of tree cover along channel banks in the project area from 1937-38 to 2000. This is likely due to a combination of factors, including lowering of the ground water table as the river bed lowered over time and as ground water pumping for irrigation became common practice in the late 1930's and early 1940's.

A visual comparison of historical aerial photographs was conducted to assess changes bank erosion and instability from 1937-38 to 2000. The amount of bank erosion in the project area in

1937-38 did not appear to be significantly different from today; however, this type of visual comparison is limited by several factors. Among them, bank erosion is typically not easily seen in aerial photographs where overhanging vegetation often obscures the river bank or in cases where the degree of erosion is not severe. Historical activities to mitigate bank erosion problems were, however, easily observed in historical aerial photographs. In particular, 1964 aerial photographs showed relatively recent bank protection works constructed along channel bends and in the vicinity of bridges throughout the project area.

3.3 Overview of Existing Channel Stability

Based on the review of the longitudinal profiles and historical planforms the following key points are listed below:

- Channel bed lowering of 4 to 26 feet has occurred since 1955 along the project reach resulting in a narrower and entrenched channel cross section as compared to historical channel morphology. Generally, channel bed lowering within the project reach increases with distance upstream of the settling basin.
- The active channel width appears to have decreased since 1937.
- The planform alignment has remained relatively constant since 1937.
- Reaches 4 and 5 exhibit the greatest degree of channel instability manifested primarily as bank erosion and bank sloughing.
- Stream gradient on Lower Cache Creek varies from about 0.0015 upstream of I-5 to about 0.00011 near the settling basin. An unusual convex-up ‘hump’ is present in the stream profile from station 580+00 to station 412+00. A grade control structure at station 557+00 is a likely contributor to the unusual profile.

4.0 FUTURE CHANNEL STABILITY

4.1 General Considerations

Cache Creek has experienced severe historical channel bed lowering (channel entrenchment) as a result of instream gravel mining, bridge and levee construction, and other factors. Due to the cessation of instream gravel mining in 1996, some future channel aggradation is expected to occur in historically mined areas along Cache Creek. Ultimately, this channel aggradation will affect the entire creek invert profile but the channel invert is not expected to return to its former historical profile within the life of this project. The rate of channel aggradation in Lower Cache Creek is expected to be low given the vast area available for gravel storage in historically mined reaches upstream of the project area. Current estimates indicate that it will take several hundred years for Cache Creek to replace the gravel removed as a result of aggregate mining (EIP, 1995).

Future channel aggradation on Lower Cache Creek will also occur as a result of sediment accumulation in the settling basin. Sediment accumulation results in a rise in base level of the downstream end of Cache Creek. As the base level rises, overall slope in the downstream part of the project area will decline, promoting sediment deposition and channel bed aggradation. As the settling basin fills, this process will migrate in an upstream direction. It is recommended that the rate of increase in base level be determined from historical topographic data of the settling basin and adjusted where possible for the effects of subsidence. If the rate of increase is substantial, channel aggradation could significantly reduce flow capacity in the downstream part of the project area during the life of the project. Mitigation of this effect can be accomplished by raising levees, excavation of accumulating sediments, channel widening, developing floodplain storage, or a combination of these activities.

Bank erosion in rivers most commonly occurs in areas where flow is concentrated along the toe of channel bank, such as on the outside of a river bend, in a reach where the channel narrows significantly, or where flows are diverted toward the bank by an in-channel island or bar. Future bank erosion sites in the project area are likely to result from one or more of these characteristics and processes. Future bank erosion in the project area will be most common in Reaches 4 and 5 due to the more narrow, sinuous, and entrenched morphology of these reaches. Based on historical records and existing morphology, the likelihood of future bank erosion should decrease with distance downstream of Reaches 4 and 5.

4.2 Future Channel Stability for Reaches 1 through 6 (Without-Project)

Future channel stability in the project area for without-project (existing) conditions is discussed in this section on a reach by reach basis. This discussion is based on information gathered from the site inspection, review of historical information, and examination of output from the HEC-RAS model of the project area for without-project conditions (Corps, 2001b).

Plots of shear stress and channel velocity were produced from a HEC-RAS model to assist in projecting the potential occurrence of future bank erosion and instability in the project area. Shear stress and velocity for the 2-year and 25-year flood flows are shown in Figures 3 and 4. The 25-year flow (41,000 cfs) represents the maximum flow capacity of Lower Cache Creek in the project area. Flows in excess of 41,000 cfs overtop the creek channel and flow overland in the floodplain. The 2-year flow is shown to illustrate typical shear stresses and velocities for lower, more frequent flows.

Examination of Figures 3 and 4 shows that shear stress and velocity are highest in Reaches 2, 3, 4, and 5 whereas Reaches 1 and 6 exhibit significantly lower values. Thus, based on simplified hydraulic estimates, Reaches 2, 3, 4, and 5 tend to be more efficient at passing sediment loads downstream and are therefore, more likely to experience significant bank erosion than Reaches 1 and 6. More detailed examination of these plots and the potential for future bank erosion and instability in each reach is provided below.

Reach 1 (station 260+00 to station 140+00)
Located in an artificial channel with a flat channel slope, flowing south into the settling basin, Reach 1 is not expected to experience significant bank erosion or bank instability in the future. Examination of year 2000 aerial photographs shows no indication of bank erosion in Reach 1. HEC-RAS model results show Reach 1 to lie in a backwater area, even at the 2-year flow discharge. Thus, flow velocities, sediment transport capacity, and shear stresses are low. Future channel bed aggradation due to ongoing sedimentation in the settling basin is expected to occur in Reach 1. This reach is likely to require aggressive sediment and vegetation maintenance.

Reach 2 (station 415+00 to station 260+00)
The potential for future bank erosion in Reach 2 is generally low with two exceptions. First, from station 415+00 to station 360+00 the potential for future bank erosion is moderate due to the presence of 3 river meanders. Future maintenance of the existing rock protection in these river meanders will likely be necessary to ensure continued channel stability. Second, Figures 3 and 4 show two large increases in local shear stress and velocity for the 25-year flow downstream of CR 102 (station 293+00). These increases are due to narrow sections in the channel that cause flows to accelerate through the constriction. There is a moderate potential for future localized bank erosion at these 2 sites.

Some channel aggradation due to sedimentation in the settling basin is expected to occur in Reach 2, though significantly less than that in Reach 1. However, Reach 2 could be affected by long-term sediment accumulation in the Settling Basin and Reach 1 if regular maintenance is not performed.

Reach 3 (station 480+00 to station 415+00) and Reach 4 (station 580+00 to station 480+00)
The potential for future bank erosion in Reaches 3 and 4 is generally moderate due to a narrow channel width, entrenchment, and steep banks. Flow velocities and shear stresses are generally higher along the channel banks of deep, narrow river reaches versus those that are more wide and shallow. River meanders in Reach 4 also present areas for future bank erosion if existing rock bank protection is not maintained. Furthermore, a relic slough channel at the outside of a bend at station 502+00 in Reach 4 should be investigated from a geotechnical perspective to ensure levee stability is not compromised. Examination of Figures 3 and 4 shows no large spikes in flow velocity or shear stress in Reaches 3 or 4 for the 2-year and 25-year flows. Instead, average values are generally higher throughout Reaches 3 and 4 when compared to the rest of the project area.

The potential for channel aggradation in Reaches 3 and 4 is low due to their elevation above the settling basin, channel dimensions, and slope. Reaches 2, 3, and 4 have higher sediment transport potential for the 25-year flood event than Reaches 1, 5, and 6 (Figure 5).

Reach 5 (station 670+00 to station 580+00)
The potential for future bank erosion in Reach 5 is high due to river meanders, entrenchment, and nearly vertical, high unstable banks in several areas. The potential for channel aggradation in this reach is low due to its elevation above the settling basin, its relatively high velocity and sediment transport capacity, and relatively low rates of future channel aggradation which are expected to occur in the historically mined reaches upstream.

Reach 6 (station 670+00 to station 780+00)
Bank erosion and instability in Reach 6 are not a significant issue for this project due to the very wide levee setbacks proposed for this reach. Over the very long term (100 to 200 years), a moderate to high amount of channel aggradation is expected to occur in this reach due to the cessation of gravel mining.

Existing channel stability was estimated by reviewing numerical results from the Corps' existing conditions HEC-RAS model (Corps, 2001). Mean channel shear stresses (tractive forces) and mean channel velocities along the project reach were reviewed for the 2, 10, and 25 year peak discharges for steady state conditions. The 25 year peak discharge, 41,000 cfs, exceeds the existing channel capacity and likely provides an upper limit on the maximum channel discharge capacity and sediment transport potential. Shear stresses range from approximately 0 to 1.3 lbs/ft^2 for the 2-year peak discharge of 12,000 cfs and from 0 to 1.8 lbs/ft^2 at a peak discharge of 41,000 cfs, the 25-year flood event. Velocities in the project reach range from 0.6 to 8 fps and 1 to 9 fps for the 2 and 25-year peak discharges, respectively. Assuming a homogeneous bed material and a critical mobility number of 0.046, Shields criteria estimates particles as large as 162 mm and 224 mm could be moved for a boundary shear of 1.3 and 1.8 lbs/ft^2, respectively. Velocities and shear stresses within the channel cross section will deviate from the average channel velocities calculated by HEC-RAS. Notably, velocities and shear stresses along the outside of bends and near obstructions such as bridge piers will likely exceed the mean channel velocity.

Allowable shear stresses calculated from flume studies for cohesive materials are below 1 lb/ft^2 (Corps, 1994). In vegetated channels with heterogeneous bank material tractive forces may exceed this value without producing appreciable bank instability (Chow 1959). The highest values of shear stress occurs near the bridges and at the transition from the wider mined channel in Reach 6 to the narrow confined channel in Reach 5. High shear stresses calculated by the model in Reach 5 correlate well with extensive bank erosion in this reach. To maintain the channel in it's current planform the channel will likely require periodic channel stabilization.

Based on the assessment of the site, historical information, examination of the Corp's HEC-RAS model and the discussion above, the following key points are listed below:

- The 25-year peak discharge represents the maximum discharge capacity in the project area.
- The potential for erosion and bank instability is greatest at constrictions (e.g. bridges) and along the outer bank at tight river bends.
- Model results indicated that Reaches 1 and 6 have the lowest sediment transport potentials and Reaches 2, 3, and 4 significantly higher sediment transport potentials during the 25-year peak flow. Therefore, sediment materials are more likely to accumulate in Reaches 1 and 6 and pass through Reaches 2, 3, and 4.
- Sediment transport potential is relatively constant through the project reach for the 2-year peak discharge.
- Channel banks in Reaches 4 and 5 are high, steep, and relatively unstable and will likely require treatment to minimize further erosion.

4.3 Future Channel Stability for Reaches 1 through 6 (With Flood Barrier Alternative)

The Flood Barrier Alternative proposes the construction of approximately 6.8 miles of levee between Cache Creek and the City of Woodland. This alternative allows the channel to function as it currently does with flows overtopping the levee and leaving the channel and flowing out onto the broad floodplain. Channel topping flows are routed over the floodplain south of the Creek to the Settling Basin. Future channel stability issues remain identical to those discussed in Section 4.2. Areas identified as potentially and currently instable are proposed to be lined with rock. In total approximately 24,100 lineal feet of rock bank protection and two rock grade control structures downstream of I-5 and SH-113 are proposed to reduce potential bank erosion in the existing channel. These stability measures in conjunction with routine inspection and maintenance appear to be sufficient to maintain channel stability over the 50-year life of the project.

4.4 Future Channel Stability for Reaches 1 through 6 (With Setback Levee Alternative)

Future channel stability in the project area for the Setback Levee Alternative is discussed in this section on a reach by reach basis. This discussion is based on information gathered from the site inspection, a review of historical information, and examination of output from the HEC-RAS model of the project area for existing (Corps, 2001)and Setback Levee Alternative (Corps, 2001b).

Plots of shear stress and flow velocity were produced from a HEC-RAS model to assist in assessing the future occurrence of bank erosion in the project area for Setback Levee Alternative. Shear stress and velocity for the with-project 25-year and 100-year flood flows are shown in Figures 6 and 7. Note that, for comparison, values for the 25-year flood under existing conditions are also shown.

Examination of Figures 6 and 7 shows several key differences between the existing design flood (25-year event) and the with-project design flood (100-year event). First, all reaches except Reach 3 exhibit an increase in average shear stress and velocity for the Setback Levee Alternative during the 100-year peak flood discharge. Second, most of the spikes in velocity and shear stress that are present under existing conditions become much more pronounced for the Setback Levee Alternative 100-year flood. These locations include the I-5 bridge complex (station 583+00), the SR 113 bridge (station 414+00), and narrow sections of the channel at stations 390+00 and 289+00. All of these locations exhibit a reduction in channel cross-section area and corresponding increase in flow velocity and shear stress as flows accelerate through these sections of the project area. Third, Reach 3 shows a very significant and abrupt decline in velocity and shear stress for the Setback Levee Alternative when compared to the existing condition. Similar but less dramatic declines are also observed in Reaches 2 and 4 where many locations show a decrease in velocity and shear stress for the Setback Levee Alternative 100-year flood. These declines are the result of backwater effects caused by bridge obstruction at SR 113 and CR 102 in the project area. Fourth, Reach 1 exhibits a significant increase in flow velocity for both the 25-year and 100-year flood flows under Setback Levee Alternative conditions. Channel shear stress and velocity more than double in the downstream half of Reach 1. This results from the modification of the training levee along Reach 1 under the Setback Levee Alternative. Generally, abrupt changes in velocity from cross section to cross section lead to localized scour and deposition, which could result in additional operations and maintenance needs or require additional channel stability measures.

Difference plots showing the change in flow velocity and shear stress from existing to the Setback Levee Alternative for the 2-, 10-, 25-, and 100-year floods are shown in Figures 8 and 9, respectively. A detailed examination of these plots and the potential for future bank erosion and instability in each reach is provided below.

Reach 1 (station 260+00 to station 140+00)
When compared to existing conditions, the Setback Levee Alternative flow velocity and shear stress exhibit a decline in Reach 1 from station 260+00 to station 239+00 (Figures 8 and 9). This decline is due to the levee offset proposed in the Setback Levee Alternative design. In contrast, Setback Levee Alternative flow velocity and shear stress increase over existing levels from station 239+00 to station 140+00 in Reach 1. This is the result of modifications that will be made to the training levee. These significant increases in flow velocity and shear stress from station 239+00 to station 140+00 indicate that future bank erosion in this section of Reach 1 will likely increase somewhat over historic levels.

Reach 2 (station 415+00 to station 260+00)
When compared to existing conditions, flow velocity and shear stress for the Setback Levee Alternative are higher at the SR 113 and CR 102 bridge crossings and at station 390+00 where the channel narrows through a tight bend (Figures 8 and 9). Bank erosion and instability in these areas for with-project conditions is expected to be higher than historic levels. In contrast, flow velocity and shear stresses are somewhat lower in other parts of the project reach for the Setback Levee Alternative, particularly downstream of CR 102. This is due primarily to the Setback Levee Alternative offset levee configuration proposed for this section of the reach. These areas are expected to show future levels of bank erosion for the Setback Levee Alternative that are similar to historic levels.

Reach 3 (station 480+00 to station 415+00)
The Setback Levee Alternative flow velocity and shear stress are lower than for existing conditions in all of Reach 3 (Figures 8 and 9). This results from the replacement of existing levees with offset levees that will be constructed throughout the project reach. Thus, bank erosion and instability in this reach for the Setback Levee Alternative is expected to be lower than historic levels.

Reach 4 (station 580+00 to station 480+00)
The Setback Levee Alternative flow velocity and shear stress are generally lower than for existing conditions from station 552+00 to station 480+00. Lower sediment transport potential during less frequent flows in this reach may lead to a new trend of sediment deposition in this reach not seen in the existing conditions. This potential trend should be addressed in the design or operations and maintenance costs. Similar to Reach 3, this results from the replacement of existing levees with offset levees that will be constructed throughout the project reach. Thus, for the Setback Levee Alternative, bank erosion and instability in this part of the reach is expected to be lower than historic levels.

From station 580+00 to station 552+00, the Setback Levee Alternative flow velocity and shear stress are higher than for existing conditions. This results from flow confinement by the I-5 bridge complex and narrower offset levees through this section of Reach 4. As a result, this section of Reach 4 is expected to experience rates of bank erosion and instability that are higher than historic levels.

Reach 5 (station 670+00 to station 580+00)
Reach 5 exhibits somewhat higher flow velocities and shear stresses for the Setback Levee Alternative than for existing conditions. This is due to increased flow confinement by the levee constructed on the north bank. Thus, rates of bank erosion and instability that are somewhat higher than historic levels can be expected in Reach 5. Concrete lining is proposed to protect against scour resulting from increases in velocity due at the I-5, 99W, and railroad bridge constriction.

Reach 6 (station 670+00 to station 780+00)
Reach 6 exhibits the lowest average values of flow velocity and shear stress for both existing and the Setback Levee Alternative. This is due to the very wide channel cross-section in this reach, resulting from historic gravel mining prior to 1996. Except for the 2-year flow, shear stress and velocity for the Setback Levee Alternative are similar to those for existing conditions. The cause of the abrupt declines in the Setback Levee Alternative velocity and shear stress for the 2-year flow in Figures 8 and 9 is due to differences in modeling of flow in the left overbank. These abrupt declines disappear in the with-project 25- and 100-year flood flows, both of which exhibit flow velocities and shear stresses similar to those for existing conditions. As a result, bank erosion and instability in Reach 6 is not expected to increase significantly for with-project conditions.

The Setback Levee Alternative increases the capacity of the existing channel by as much as 2.3 times, from 30,000 cfs to 70,000 cfs, by installing setback levees while maintaining the existing channel configuration. These modifications effectively increase conveyance capacity during flood events with return periods greater than the 25-year flood event. Along with increases in flood stage, the alternative also increases in-channel velocity and shear stresses in some locations, most notably in areas of channel constrictions (e.g. bridges). Calculated shear stresses and velocities at the bridges are estimated to be as high as 2.9 lbs/ft^2 and 14.5 fps, respectively. Figures 6 and 7 show shear stress and velocity profiles along the project reach. Lower channel velocities and shear stresses upstream of bridges occur as a result of increased floodplain conveyance and backwater conditions at bridge constrictions. Calculated shear stresses and velocities are reduced by as much as 0.7 lbs/ft and 2.3 fps upstream of bridge structures as a result of these modifications. To prevent bank erosion rock bank protection is proposed by CDM in areas where model results calculate high channel velocities (greater than 6 to 8 fps). Figure 9 shows the relative differences in shear stress between the Setback Levee Alternative and existing conditions for the 2, 10, 25, and 100-year peak discharges.

The proposed setback levee design was reviewed with respect to potential impacts to main channel stability. The present channel configuration has a design capacity of 30,000 cfs (Corps 2001). The setback levee alternative proposes to increase the overall channel capacity to 70,000 cfs, corresponding to the 200-year peak flood discharge by removing or raising sections of the existing levee and constructing new levees setback from the existing channel. In-stream stability measures developed by CDM (Corps, 2001b) to stabilize the creek include constructing approximately 5.7 miles of rock bank protection and lining the bridge inverts with concrete. Based on initial review of calculated shear stresses and channel velocities from the HEC-RAS project conditions model, these stability measures with routine inspection and maintenance appear to be sufficient to maintain channel stability for the 50 year life of the project. However, a significant increase in maintenance could result with this alternative because it promotes several abrupt changes in flow characteristics within the project reach during less frequent flood events. River morphology tends to adjust in plan and profile to reduce abrupt changes in hydraulic and sediment transport characteristics.

Alternative methods of bank protection such as rock groins, barbs, channel widening, and reducing bank slopes could reduce the amount and cost of the rock bank protection for the Setback Levee Alternative. The use of rock structures, such as streambarbs, to reduce velocities on the outside of bends and the construction of benched surfaces could potentially reduce the rock bank protection needs, conceivably by as much as 25 percent. However, these structures typically have higher design costs, unit construction costs and require more area for bench construction than rock blankets. A further increase in the distance between the setback levees and the channel reduces the potential for the channel to migrate into the levee prism. Construction of setback levees and removal of the existing levees helps to reduce in-channel velocities and depths at discharges greater than bankfull between constrictions. In the Setback Levee Alternative, flows contained within the setback levees return to the channel at constriction points, i.e. bridges, substantially increasing channel velocities and shear stresses at these locations than under existing conditions. These areas will require engineered re-entry points to prevent bank erosion and gully formation in the floodplain. The construction of this alternative dramatically changes the in channel hydrologic regime during less frequent, channel topping flood flows and should therefore be designed to minimize abrupt changes in hydraulic characteristics.

5.0 OPERATIONS AND MAINTENANCE

DWR reports the annual operations and maintenance costs of $10,000/mi in the Lower Cache Creek channel (McQuirk 2001). Current O&M consists primarily of channel clearing, weed abatement, and rodent impact management (Romero 2001). Maintenance to stabilize the channel and banks has not been conducted for the last 15 to 20 years. However, the recent high flows in 1995 and 1997 have caused bank erosion in three sites in the project reach. DWR is investigating these bank erosion sites. Cost estimates for these activities were not available at the time of this reporting.

The 1958 Yolo Bypass to High Ground Levee Construction General Design Memorandum states that 6410 lineal feet of stone protection was to be placed in the channel. At the time of this writing the construction of the stone protection could not be confirmed by the USACE or DWR (Boedtker 2001, McQuirk 2001). DWR does not currently maintain any rock bank protection within the main channel of Cache Creek in the project reach (Romero 2001).

Construction of the Setback Levee Alternative increases the range of flood events conveyed within the channel. To mitigate against higher anticipated boundary shear stresses approximately 5.7 miles of rock bank protection is proposed. Increases in boundary shear and the routine maintenance of the proposed rock bank protection will increase O&M costs above existing O&M costs. Within those regions in Reaches 1, 2, 3, and 4 where average velocities and shear stress are reduced, sediment accumulation may occur, potentially requiring future maintenance to remove deposits. This increase will include routine maintenance on the existing rock and maintenance of channel banks during large flood events. An approximate annual O&M cost for the Setback Levee Alternative is 0.014 x total project rock cost + weed abatement and rodent control.

Based on the information provided by DWR, examination of the Corp's HEC-RAS model and the discussion above, the following key points are listed below:

- Current maintenance practices are focused on annual channel clearing, weed abatement, and rodent impact management. Channel stabilization activities are conducted infrequently as they are deemed necessary.
- To ensure satisfactory performance of rock bank protection, rock work should be annually inspected and periodically maintained.
- Current Corps and DWR maintenance records of Cache Creek and similar channels should be reviewed to more accurately identify maintenance costs for proposed alternatives.
- Design of selected the project alternative should consider changes in flow hydraulics to estimate potential maintenance requirements.

6.0 SETTLING BASIN

The project impacts on the Settling Basin were assessed using existing analyses and information published in the Investigations of Alternative Plans for Control of Sediment from Cache Creek (DWR, 1968), the Cache Creek Settling Basin Final General Design Memorandum (Corps, 1987), and numerical results calculated from the MBK FLO-2D model of the Settling Basin for the existing conditions and the Flood Barrier Alternative. Both the 1968 DWR and 1987 USACE reports assess sediment deposition and trap efficiency in the Settling Basin.

Measured sediment data has been collected on Cache Creek at Yolo since 1943 to present. The Corps (1987) reports that 93 percent of the total sediment load passing the Yolo gage is suspended sediment with the remaining 7 percent transported as bed load. Approximately 86 percent of the suspended load at Yolo is less than 0.064 mm, silts and clays.

The annual suspended sediment inflow into the Settling Basin between 1904 and 1963 is estimated to be 675 acre-ft (DWR 1968). An annual deposition rate of 340 acre-feet was calculated between 1934 and 1968 (DWR 1968). The 1987 USACE estimate of trap efficiency through time is shown in Figure 10. This estimate for trap efficiencies is based on the current channel design capacity of 30,000 cfs and training levee configuration. Raising the Settling Basin outlet weir 25 years from initiation of the project produced an average trap efficiency of 55 percent over a 50 year period. Assuming that time zero corresponds with the date of construction, 1991, then the analysis estimates a trap efficiency of approximately 45 percent at the time of this writing, 2001. Sediment loadings from single flood events were not identified in the DWR and Corps reports.

The proposed Setback Levee alternative and the Flood Barrier Alternatives affect the Settling Basin performance in several ways. These alternatives route more water and sediment into the Settling Basin than would have otherwise left the channel onto the floodplain and not entered the channel under the current conditions. In doing so, these alternatives increase the magnitude of maximum inflow and outflow discharges and volume of runoff entering the basin during flood events. Generally, both flood control alternatives will reduce the sediment storage capacity at a more rapid rate, thereby more rapidly reducing the trap efficiencies through time than under current channel conditions. Quantification of the changes in rates is beyond the scope of this study, but should be assessed for project design. Presumably, with the Flood Barrier Alternative much of the sediment will deposit in overbank areas, south of the Cache Creek, before returning to the settling basin creating a much smaller increase in peak discharge and sediment inflow than would the Setback Levee Alternative which routes flood flows with a relatively high sediment transport potential directly to the Settling Basin. The Flood Barrier Alternative should have a significantly lower impact to the overall long-term performance of the basin than the Setback Levee Alternative.

Velocities in the basin during the peak inflowing discharges for the 50 and 200-year flood events were reviewed to assess the potential impact on deposition of fine sediments and scour during high flow. Figures 11, 12, and 13 show maximum velocity contour maps of the entire simulation period. These contour data were generated from FLO-2D data provided by MBK. The existing conditions plan simulates the existing channel and Settling Basin conditions. Plan A simulates the Flood Barrier Alternative with a 4,000 feet section of the west settling basin weir removed. Flood hydrographs for the 50-year and 200-year flood events were routed from Road 94B. The peak discharge entering the Settling Basin in the existing conditions is 25,300 cfs. The peak discharge entering the Settling Basin for the Flood Barrier Alternative is 37,000 and 45,600 cfs for the 50-year and 200-year flood events, respectively. Maximum velocities through the settling basin for the existing conditions 50-year flood event, 53,000 cfs range from 8 fps at the training levee outlet to a low near 0 fps in the lee of the training levee. The Flood Barrier Alternative, Plan A, calculates a velocities range similar to the existing conditions. Comparison between the maximum velocities shows that generally maximum velocities are 1 and 3 fps for the majority of the basin in each of the three plots. Plan A would increase velocities by less than 1 fps through most of the basin over existing conditions. Comparison of the velocities between the existing conditions and Plan A at a discharge of 70,000 cfs indicates basin maximum velocities will increase approximately 0 to 1.5 fps throughout most of the basin with larger increases occurring near the inlet of the basin. Maximum velocities for Plan A for a discharge of 70,000 cfs range from 1 to 5 fps throughout most of the basin with higher velocities at the inlet to the basin. . Permissible velocities range from 1 to 6.5 fps for loosely to very compacted cohesive soils. These relatively small increases of 1 to 1.5 fps in maximum velocity are unlikely to induce significant scour of the bottom sediments. Increases in maximum velocities indicate the impact of the Flood Barrier Alternative on resuspension of deposited material in the Settling Basin is likely low.

Future analysis could assess how time dependant changes in velocity influence trap efficiency and particle resuspension in the Settling Basin.

7.0 CONCLUSIONS & RECOMMENDATIONS

The qualitative geomorphic, and channel stability assessment conducted by nhc in the development of this memorandum is based on the review of readily available information. Furthermore, detailed study of the issues discussed herein is recommended prior to final design of the selected flood control alternative.

Under existing conditions the channel has remained generally stable in its planform with significant degradation of the invert since 1938. Flood events in excess of bankfull generally produce erosive velocities that may lead to bank erosion. Extended periods of high flows may induce sloughing of saturated banks as flows recede. Reaches 4 and 5 (Figure 1) exhibit signs of moderate to high channel instability. These reaches may suffer extreme bank erosion during storm flows. Stabilization measures are recommended in these reaches to maintain channel stability.

The Flood Barrier Alternative maintains the current channel capacities while stabilizing the areas identified as unstable. Additionally, this alternative has a significantly lower impact on routing flows to the Settling Basin. Flows overtopping the north levee are distributary to the Settling basin. Flows overtopping the south are conveyed across the floodplain at low velocities and shallow depths allowing time for infiltration, attenuation, and sediment deposition on floodplain. The Flood Barrier Alternative will have a significantly lower affect on Settling Basin sediment accumulation rates and trap efficiency than the Setback Levee Alternative. Quantification of sediment accumulation rates and changes in trap efficiencies are beyond the scope of this report but should be investigated prior to design.

The Setback Levee Alternative increases the current design capacity of the channel by approximately 2.3 times to 70,000 cfs. The significant increase in the magnitude and volume of flow that will be contained by the Setback Levee Alternative is likely to increase channel velocities and shear stresses during high flow events. Mitigation for the increase in velocity and shear stress will require substantial placement of bed and bank stabilization features (e.g. rock slope protection). Complete containment of flow with the Setback Levee Alternative will increase the total volume and magnitude of flow and sediment to the Settling Basin for events greater than channel topping flows. Rock slope protection is proposed along approximately 5.7 miles of bank to prevent erosion resulting from increase velocities for this alternative.

Qualitative assessment of the Settling Basin performance is based on previous studies (Corps, 1968; Corps, 1987). These studies calculated an annual trap efficiency of approximately 340 acre-feet. Over time as deposition occurs within the basin the trap efficiency of the basin is estimated to decrease. Figure 10 plots computed trap efficiency with time for the current conditions. Due to the more efficient routing characteristics of the Setback Levee Alternative the Settling Basin trap efficiency is presumed to decrease more rapidly with the construction of the Setback Levee Alternative than under both the current conditions and the Flood Barrier Alternative. Further analyses are required to recomputed expected changes in basin trap efficiencies for various project changes.

7.1 Key Unresolved Issues and Data Needs for Further Study and Project Design

- Future channel bed aggradation in Reaches 1 and 2 resulting from Settling Basin aggradation needs to be quantified and incorporated in design to ensure flow capacity;
- Channel stability due to abrupt local changes in transport potential, observed primarily for the Setback Levee Alternative should be assessed;

- Under the Setback Levee Alternative, further analyses and/or design are required to ensure bank erosion and gully formation in the floodplain does not occur as a result of flows reentering the channel from the floodplain.
- Changes in sediment supply (sediment loading) to the project reach as a result of the cessation of in-channel gravel mining should be quantified to determine the impact on the project alternatives and Settling Basin performance;
- The potential for levee instability at Station 502+00, the location of a relic slough channel, due to subsurface flow should be investigated.
- Measures to prevent bank erosion and gully formation in the floodplain as a result of flows reentering the channel under the Setback Levee Alternative should be designed.

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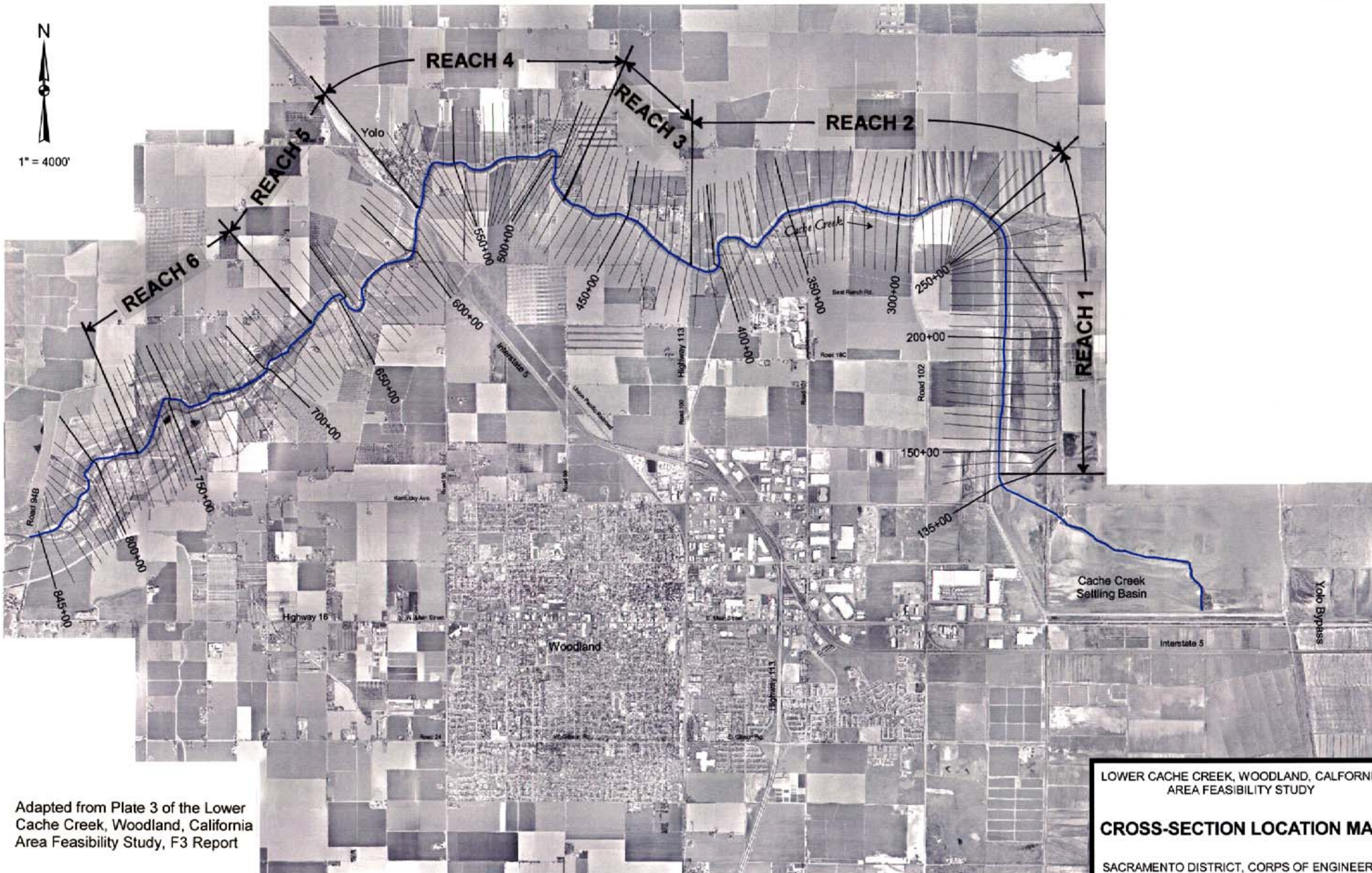


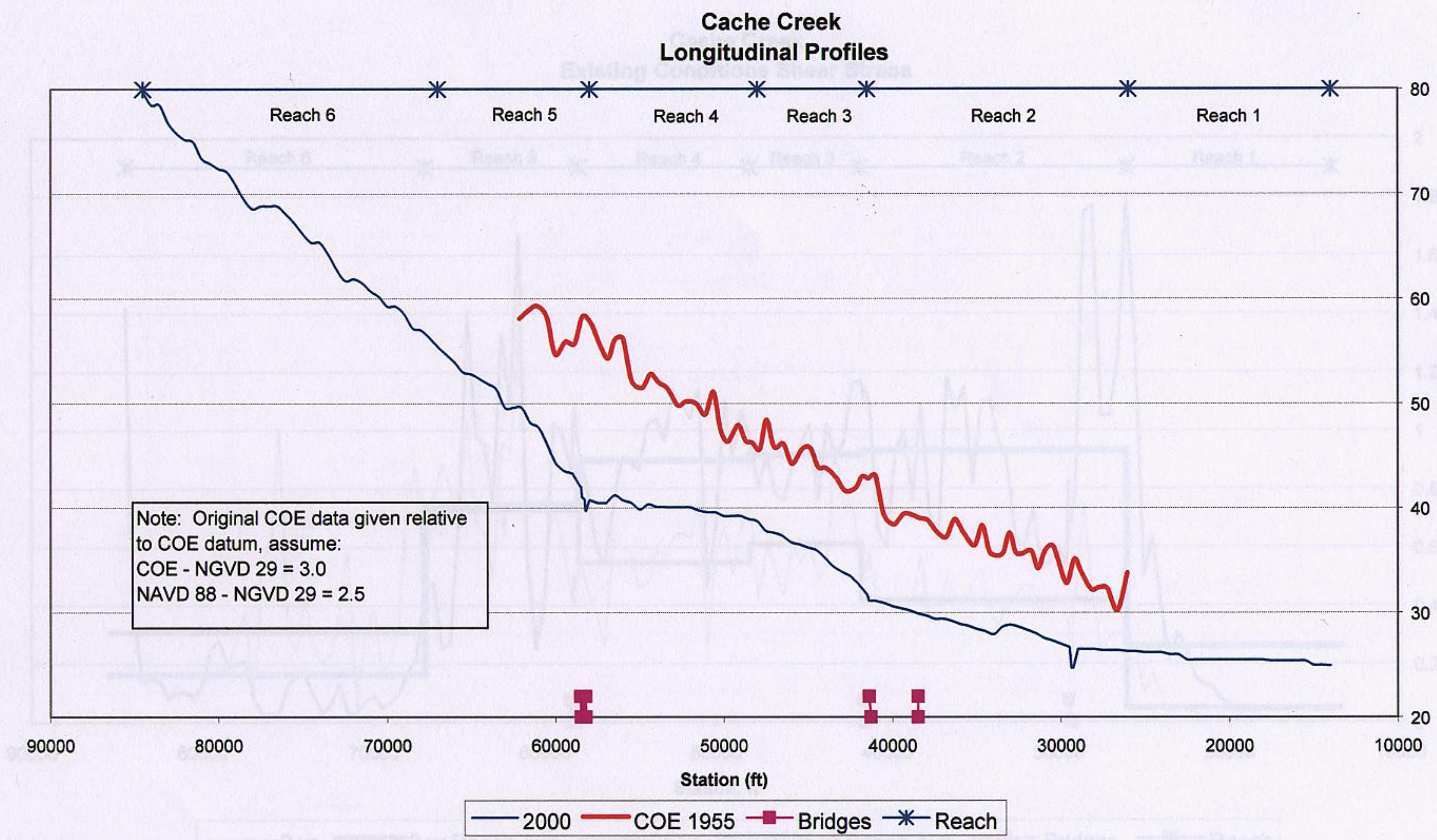
Adapted from Plate 3 of the Lower Cache Creek, Woodland, California Area Feasibility Study, F3 Report

LOWER CACHE CREEK, WOODLAND, CALFORNIA
AREA FEASIBILITY STUDY

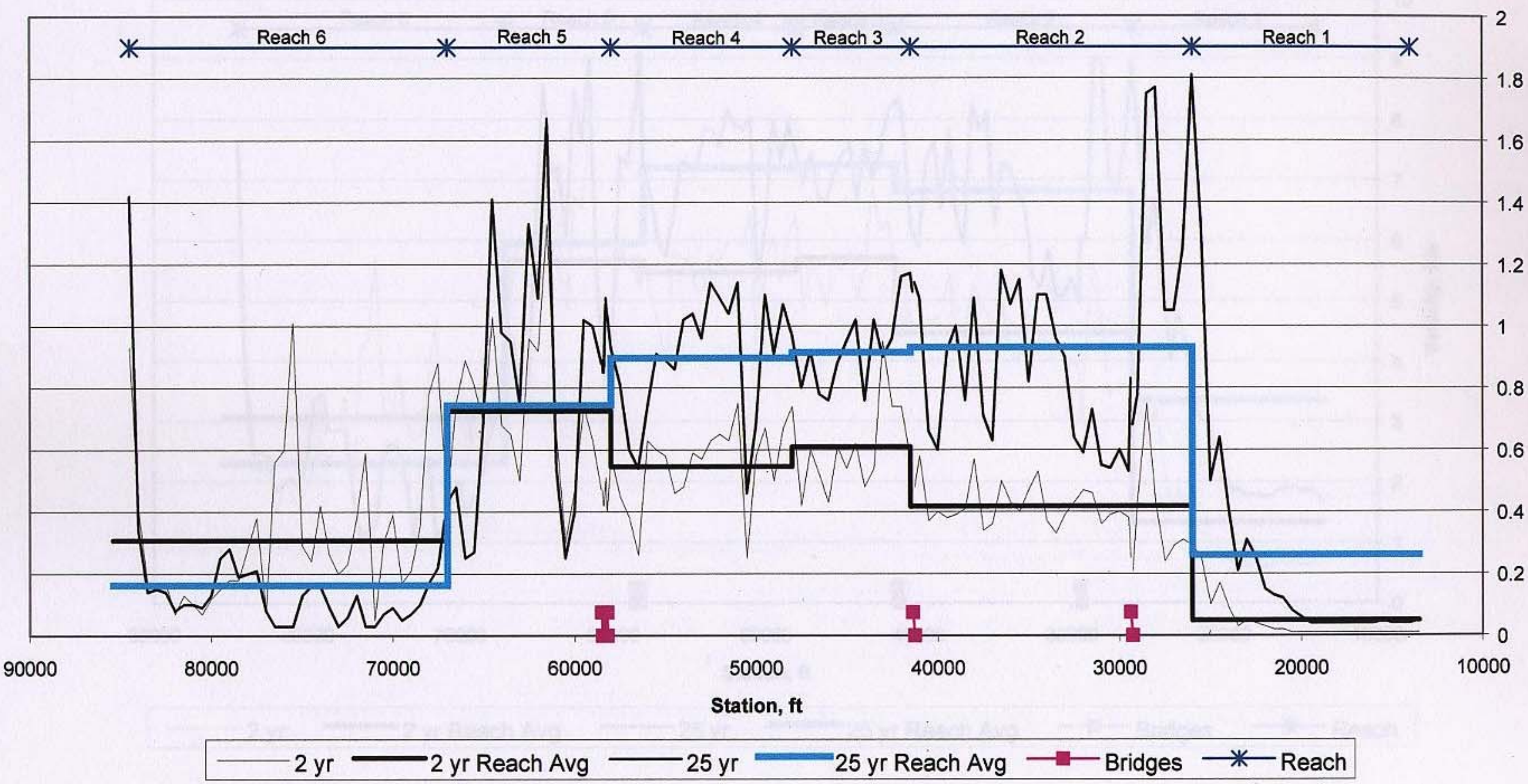
CROSS-SECTION LOCATION MAP

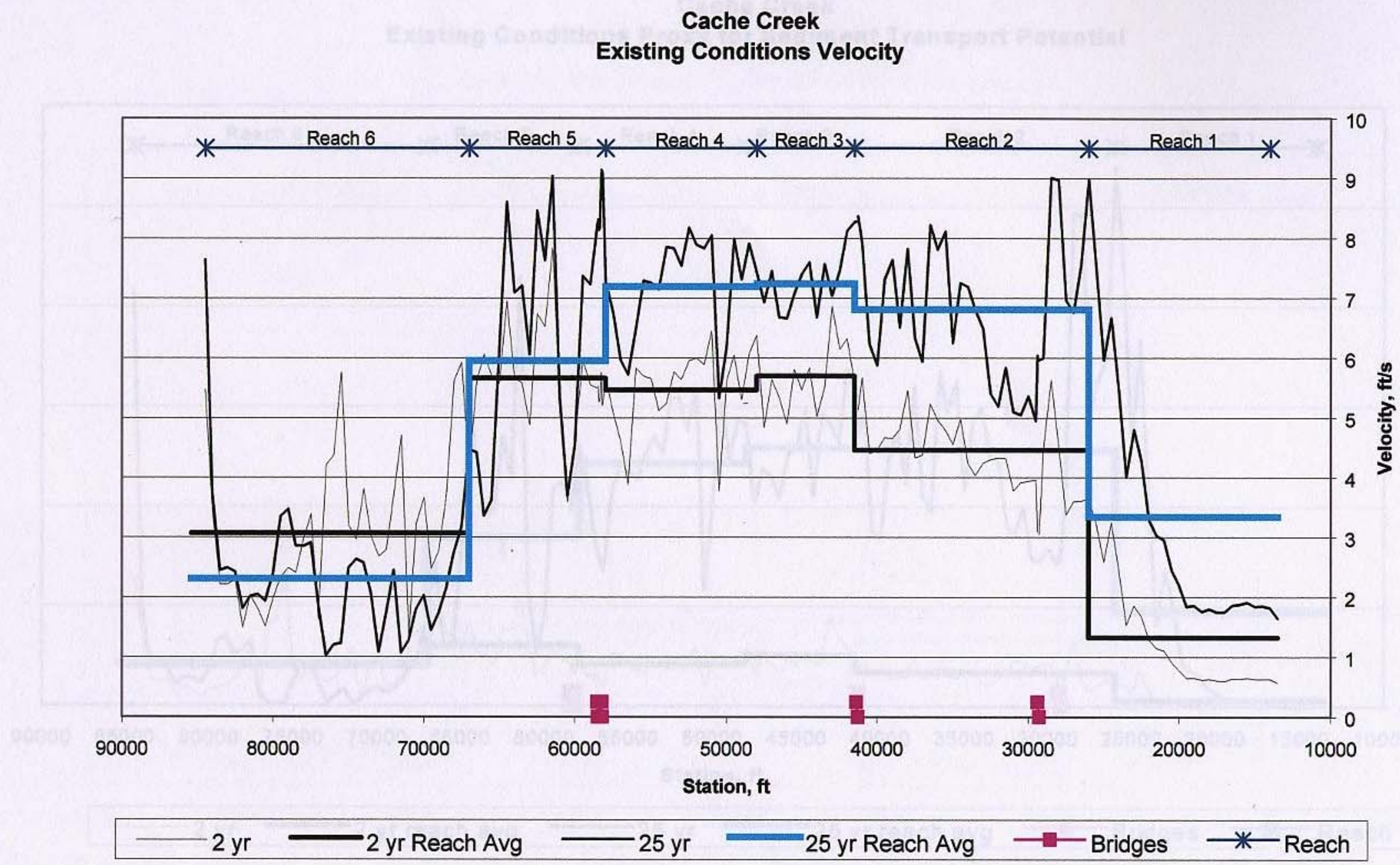
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 2001

Figure 1

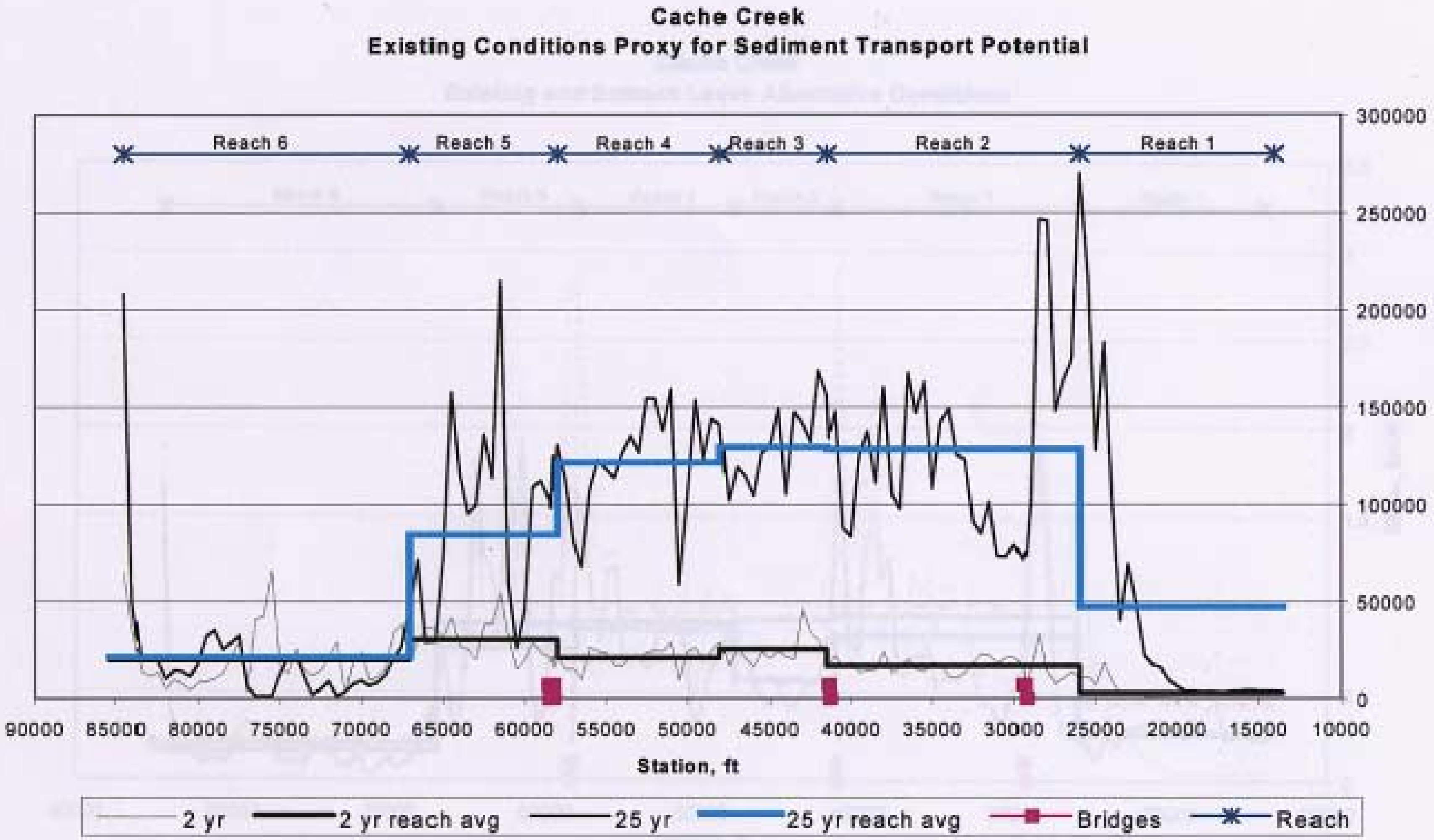

Cache Creek
Longitudinal Profiles
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
Note: Original COE data given relative to COE datum, assume:
COE - NGVD 29 = 3.0
NAVD 88 - NGVD 29 = 2.5
80
70
60
50
40
30
20
Elevation (ft, NAVD88)
90000
80000
70000
60000
50000
40000
30000
20000
10000
Station (ft)
2000
COE 1955
Bridges
Reach

Cache Creek
Existing Conditions Shear Stress

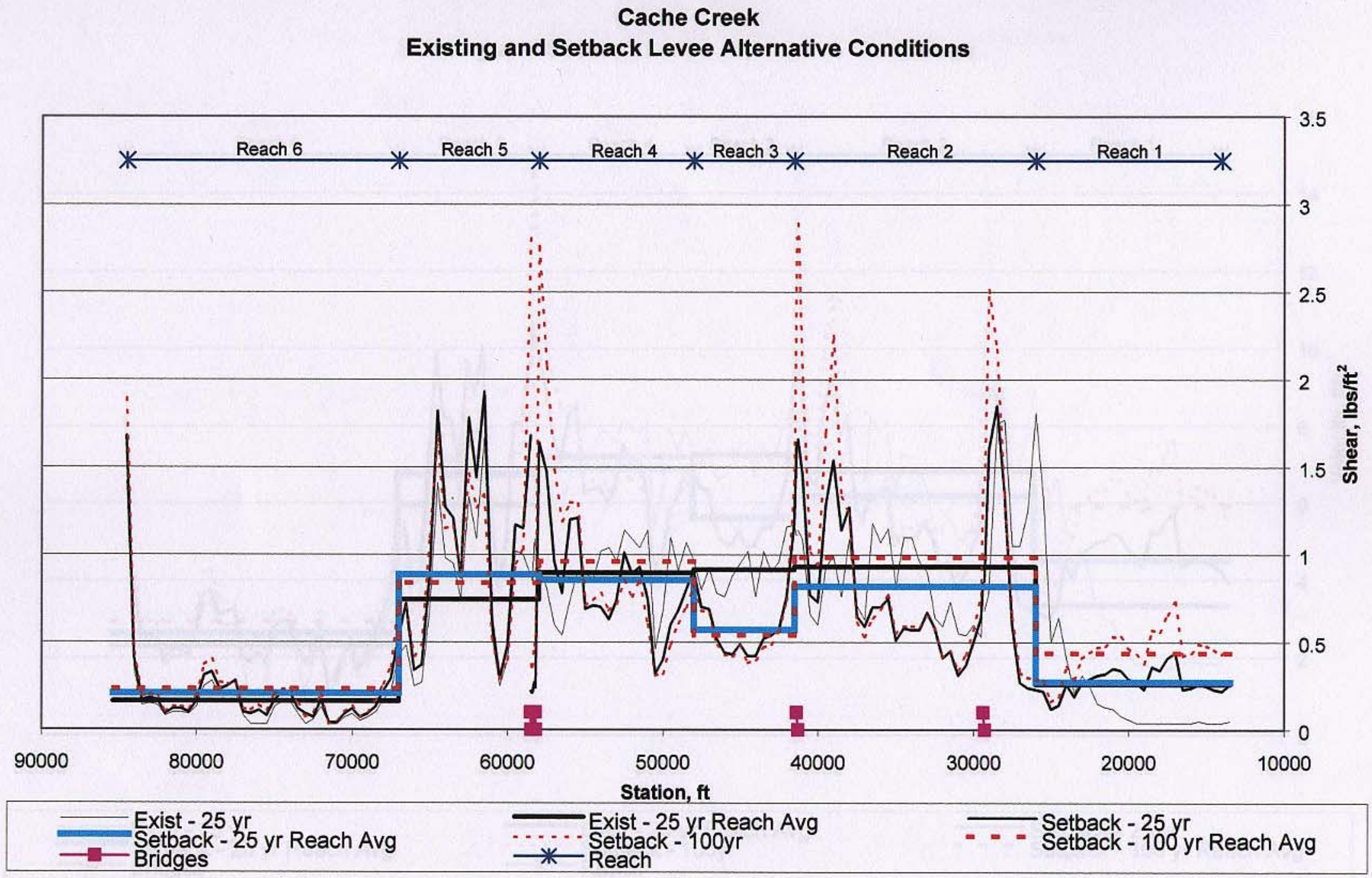


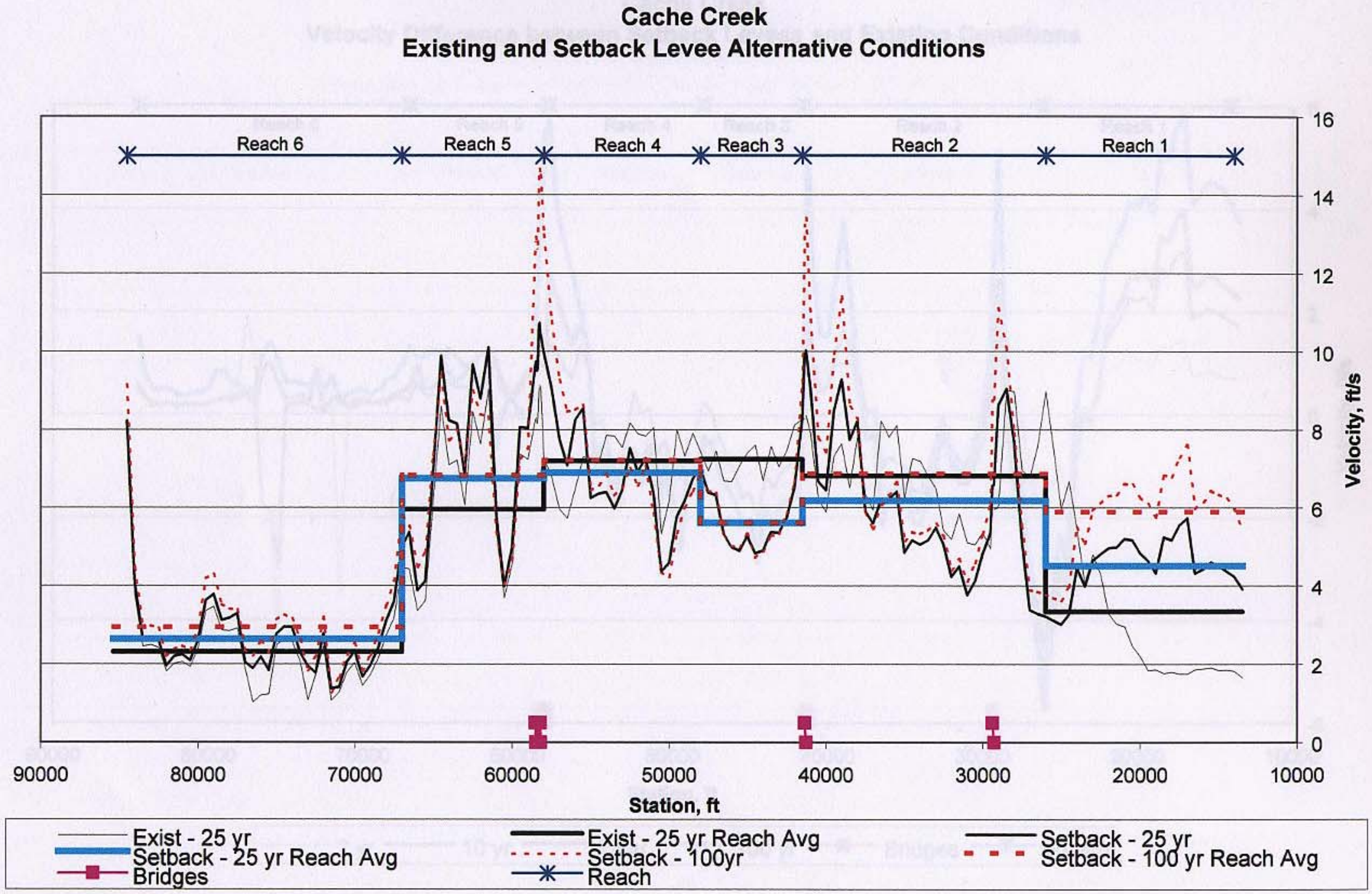


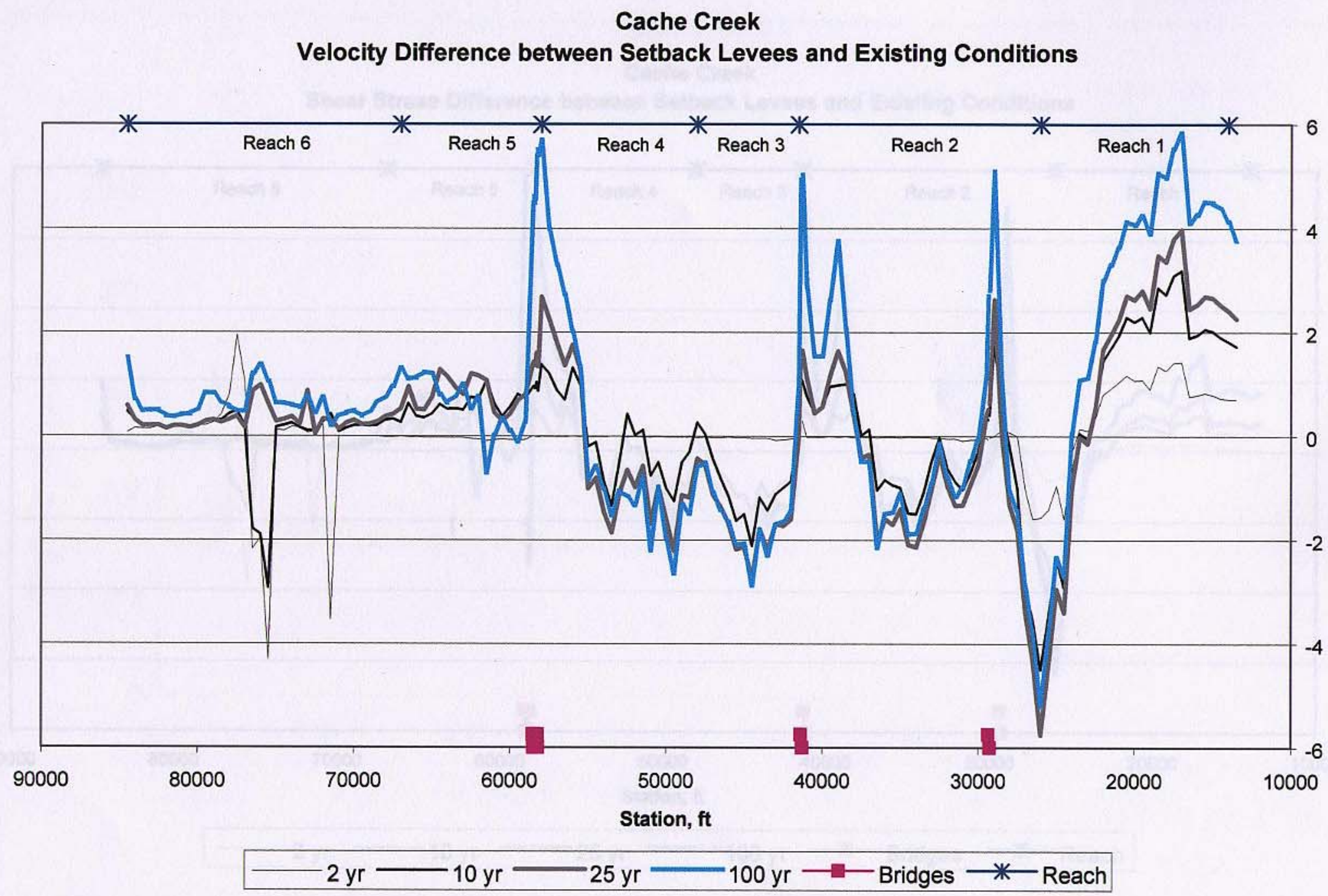
Cache Creek
Existing Conditions Velocity
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
Velocity, ft/s
10
9
8
7
6
5
4
3
2
1
0
90000
80000
70000
60000
50000
40000
30000
20000
10000
Station, ft
2 yr
2 yr Reach Avg
25 yr
25 yr Reach Avg
Bridges
Reach

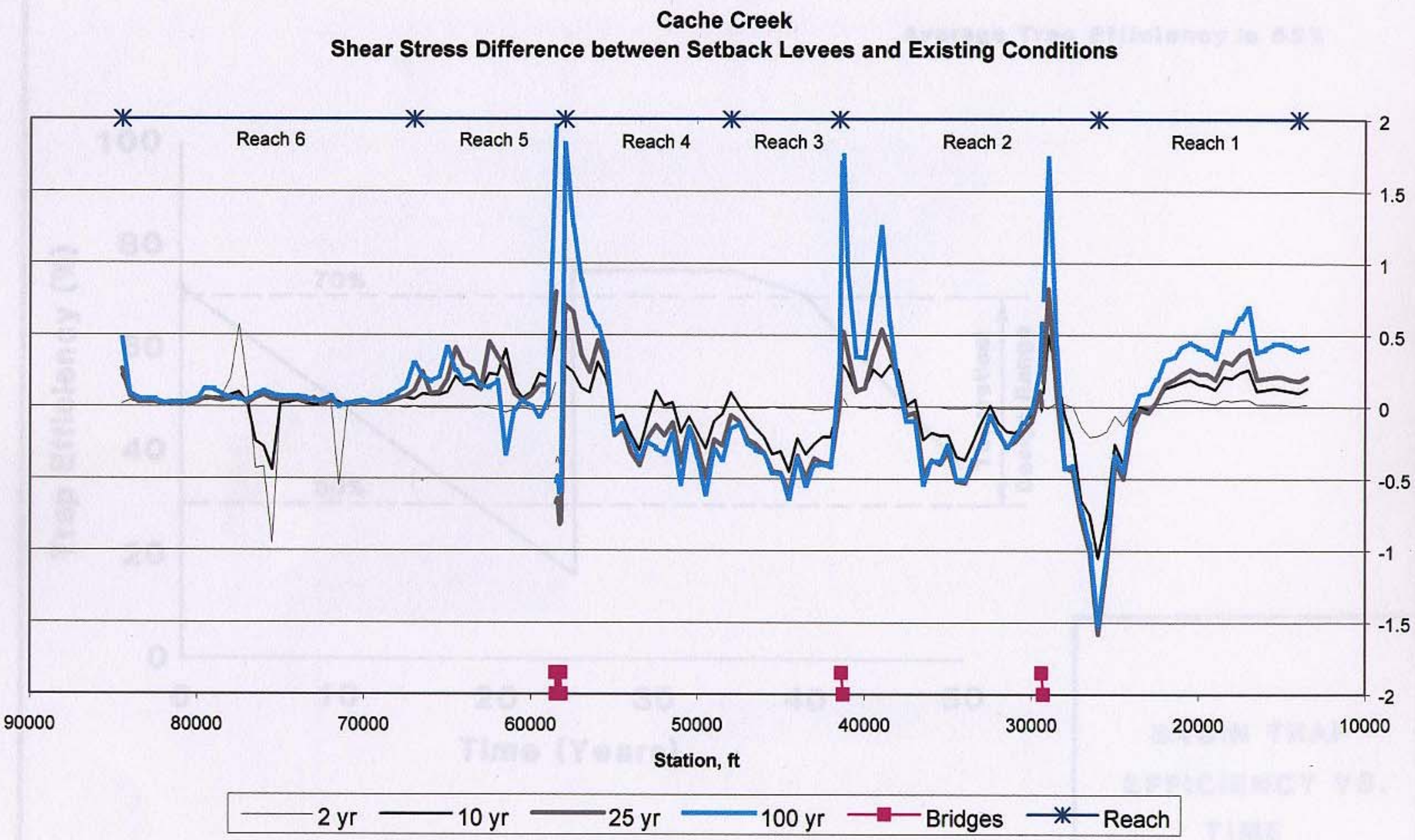


Cache Creek
Existing Conditions Proxy for Sediment Transport Potential
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
300000
250000
200000
150000
100000
50000
0
V²W (channel vel² x width)
90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
Station, ft
2 yr
2 yr reach avg
25 yr
25 yr reach avg
Bridges
Reach

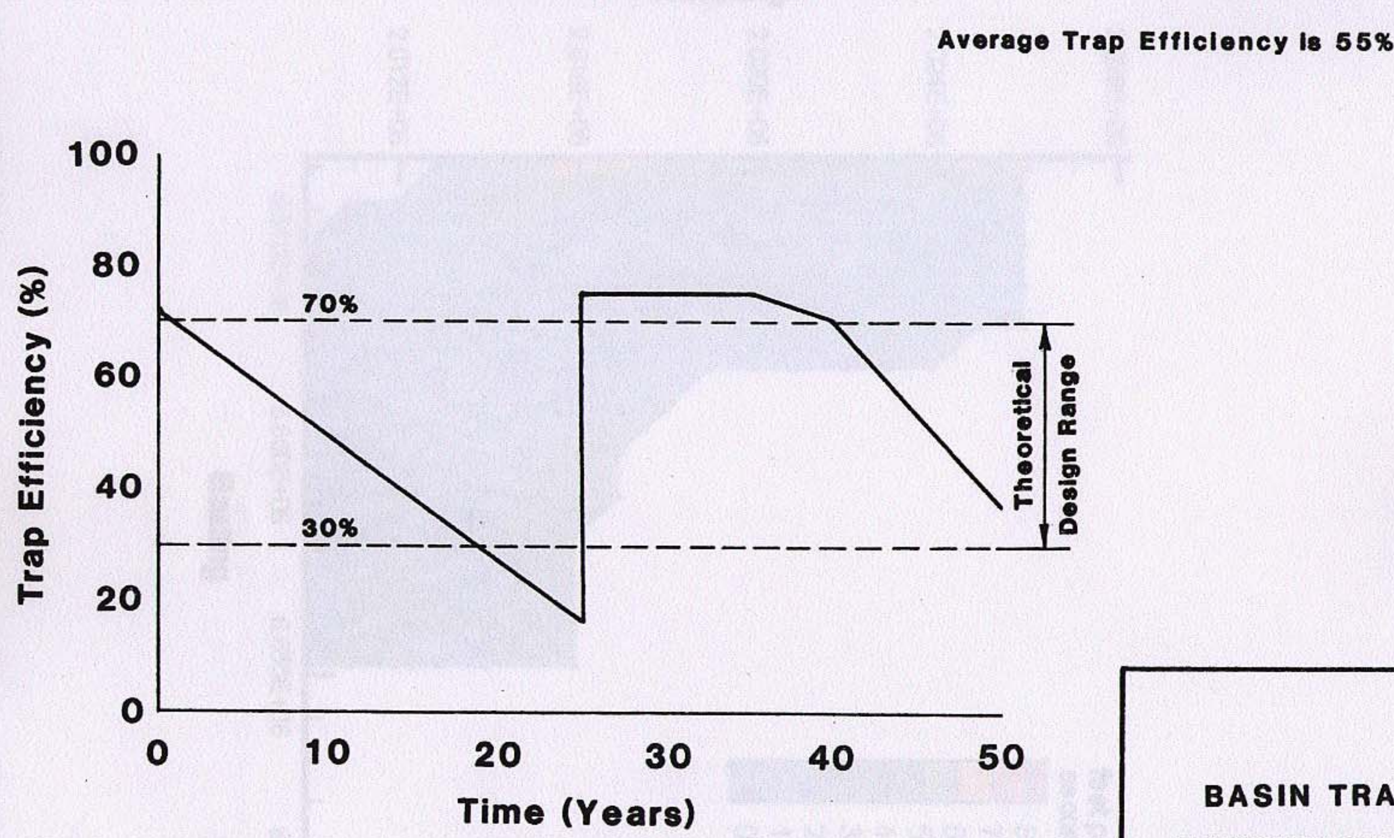

Cache Creek
Existing and Setback Levee Alternative Conditions
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
3.5
3
2.5
2
1.5
1
0.5
0
Shear, lbs/ft²
90000
80000
70000
60000
50000
40000
30000
20000
10000
Station, ft
Exist - 25 yr
Setback - 25 yr Reach Avg
Bridges
Exist - 25 yr Reach Avg
Setback - 100yr
Reach
Setback - 25 yr
Setback - 100 yr Reach Avg


Cache Creek
Existing and Setback Levee Alternative Conditions
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
Velocity, ft/s
Station, ft
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
2
4
6
8
10
12
14
16
Exist - 25 yr
Setback - 25 yr Reach Avg
Bridges
Exist - 25 yr Reach Avg
Setback - 100yr
Reach
Setback - 25 yr
Setback - 100 yr Reach Avg

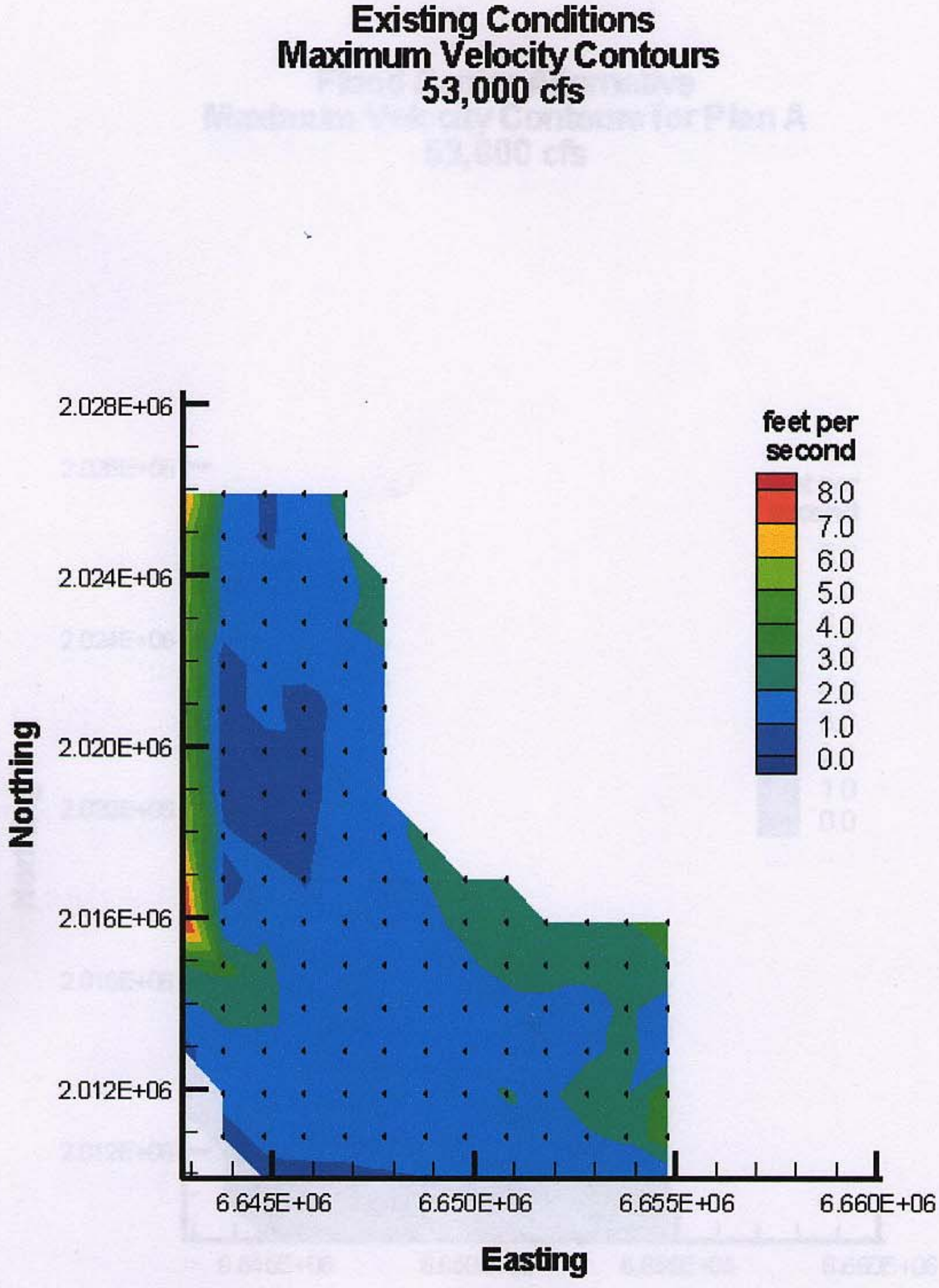

Cache Creek
Velocity Difference between Setback Levees and Existing Conditions
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
6
4
2
0
-2
-4
-6
Velocity, ft/s
90000
80000
70000
60000
50000
40000
30000
20000
10000
Station, ft
2 yr
10 yr
25 yr
100 yr
Bridges
Reach



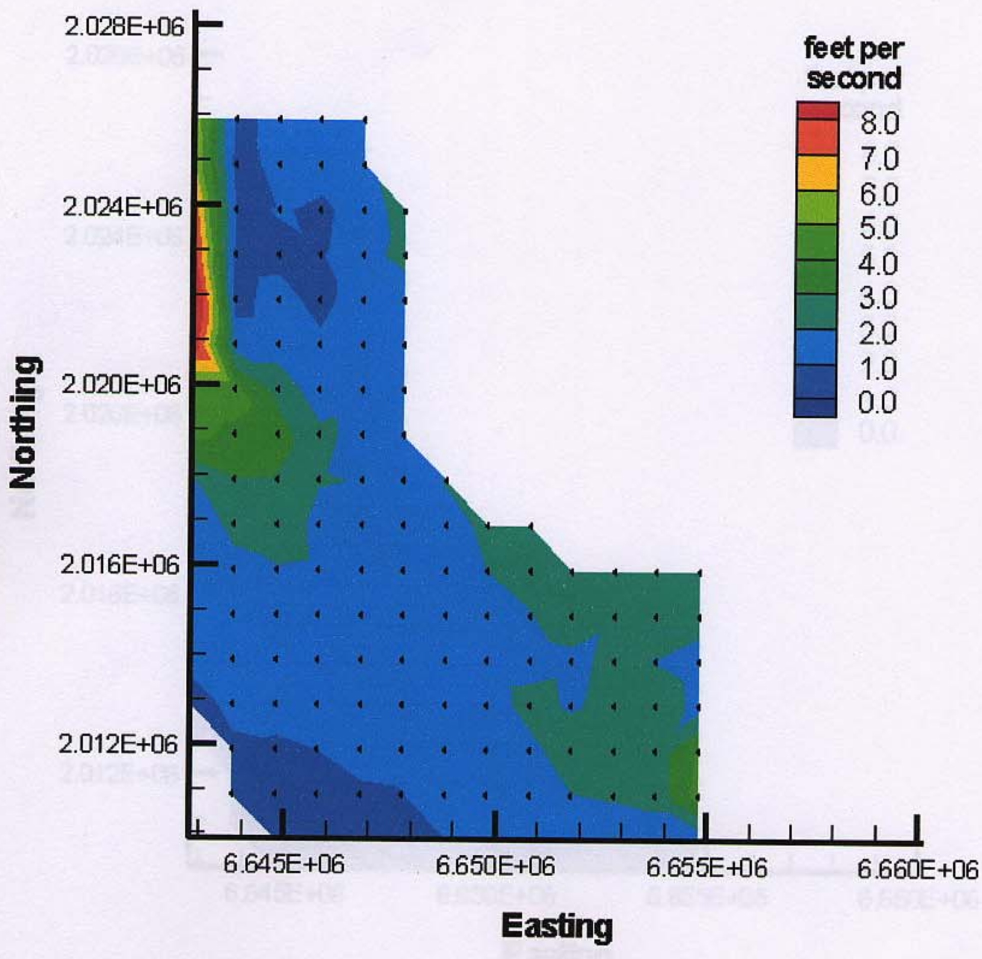
Cache Creek
Shear Stress Difference between Setback Levees and Existing Conditions
Reach 6
Reach 5
Reach 4
Reach 3
Reach 2
Reach 1
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Shear Stress, lbs/ft^2
90000
80000
70000
60000
50000
40000
30000
20000
10000
Station, ft
2 yr
10 yr
25 yr
100 yr
Bridges
Reach

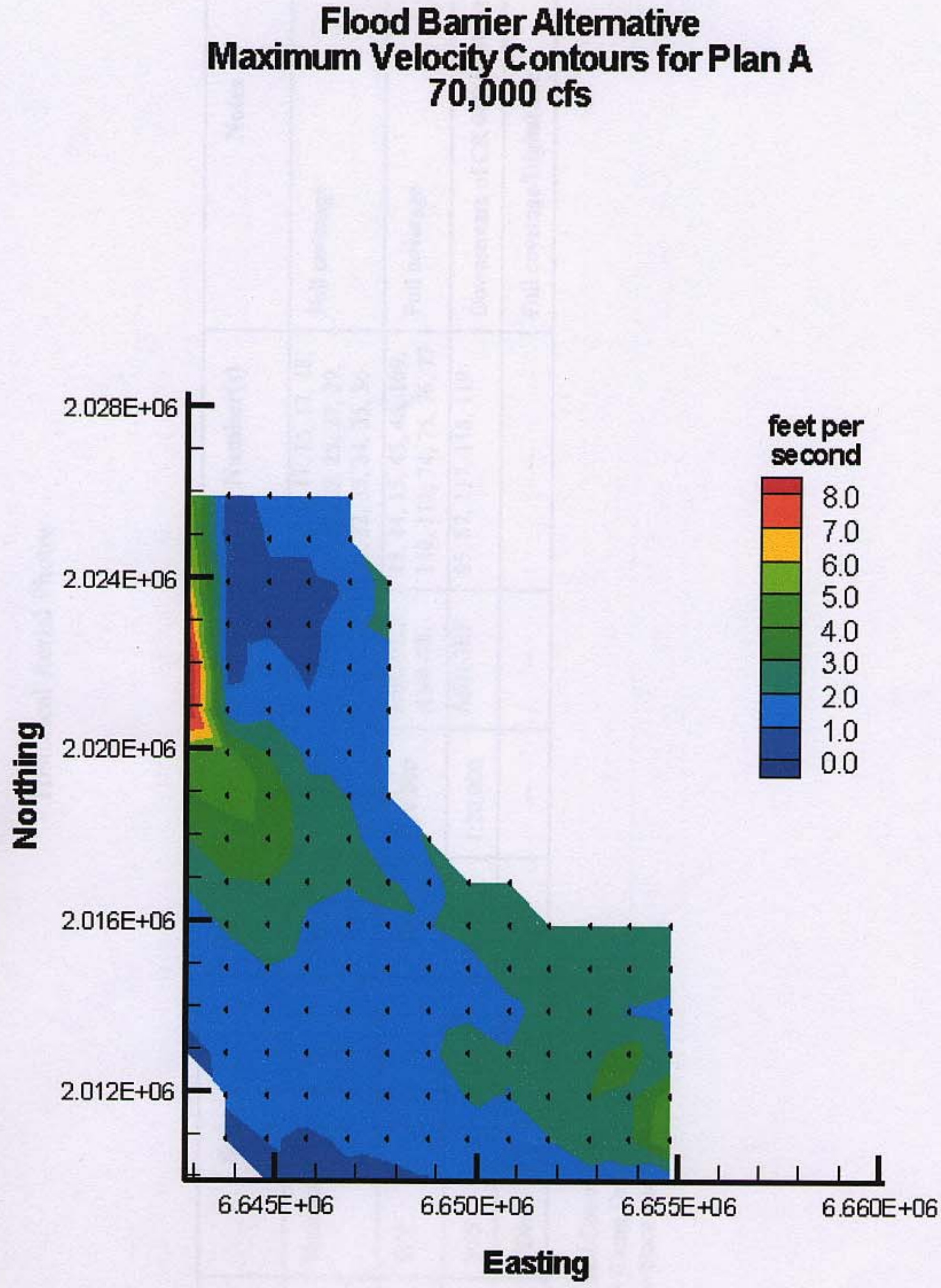


BASIN TRAP EFFICIENCY VS. TIME


Existing Conditions
Maximum Velocity Contours
53,000 cfs
2.028E+06
2.024E+06
2.020E+06
2.016E+06
2.012E+06
Northing
6.645E+06
6.650E+06
6.655E+06
6.660E+06
Easting
feet per second
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

Flood Barrier Alternative
Maximum Velocity Contours for Plan A
53,000 cfs




Flood Barrier Alternative
Maximum Velocity Contours for Plan A
70,000 cfs
2.028E+06
2.024E+06
2.020E+06
2.016E+06
2.012E+06
Northing
6.645E+06
6.650E+06
6.655E+06
6.660E+06
Easting
feet per second
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

Historical Aerial Photos

Aerial Photo Date	Source	B&W/ Color	Scale	Series	Print Number(s)	Notes
1937	National Archives	B&W	1:20,000	--	5, 7, 13, 11, 15, 17, 18, 19, 21, 23, 25, 27, 29, 31, 32, 33, 34, 35, 36	Full coverage
1952	SCS	B&W	1:20,000	ABB-3K, ABB-5K	13, 14, 15, 45, 46, 109, 110, 111; 74, 75, 76, 77	Full coverage
1964	SCS	B&W	1:20,000	ABB-3EE	85, 87, 117, 118, 119	Downstream of CR 94B to SR 113
2000	CDM	B&W	--	--	--	Full coverage/Digital File

Notes: SCS = Soil Conservation Service
CDM = Camp Dresser McKee
B&W = black and white

Historical Topographic Maps

Map Name	Author	Edition	Surveyed	Scale	Contour Interval (feet)	Notes
Madison	USGS	1968	1953	1:24,000	5	Photorevised with 1968 aerial photographs
Grays Bend	USGS	1953	1953	1:24,000	5	
Woodland	USGS	1981	1952	1:24,000	5	Photorevised with 1981 aerial photographs
Madison	USGS	1980	1953	1:24,000	5	Photorevised with 1980 aerial photographs
Grays Bend	USGS	1975	1953	1:24,000	5	Photorevised with 1968 and 1975 aerial photographs
Woodland	USGS	1952	1952	1:24,000	5	
Madison	USGS	1953	1953	1:24,000	5	
Woodland	USGS	1968	1952	1:24,000	5	Photorevised with 1968 aerial photographs

Lower Cache Creek Reach Average Characteristics

Reach	Active Top Width				Max Flow Depth			
	Existing Cond 2-year Flow	Prop Cond 2-year Flow	Existing Cond 100-year Flow	Prop Cond 100-year Flow	Existing Cond 2-year Flow	Prop Cond 2-year Flow	Existing Cond 100-year Flow	Prop Cond 100-year Flow
1	592	602	624	649	17.0	17.4	19.6	23.8
2	199	212	415	420	19.8	20.3	30.6	31.7
3	135	136	338	354	19.8	20.0	35.0	37.0
4	128	128	327	318	21.7	21.8	38.9	38.1
5	170	171	432	460	19.5	19.6	38.0	40.5
6	767	777	1255	1292	13.7	13.8	25.7	29.2

Reach	Mean Flow Depth*				Energy Slope**			
	Existing Cond 2-year Flow	Prop Cond 2-year Flow	Existing Cond 100-year Flow	Prop Cond 100-year Flow	Existing Cond 2-year Flow	Prop Cond 2-year Flow	Existing Cond 100-year Flow	Prop Cond 100-year Flow
1	9.0	9.2	10.8	14.6	0.00008	0.00013	0.00040	0.00052
2	12.7	12.6	14.4	15.3	0.00062	0.00060	0.00119	0.00120
3	13.7	13.8	16.0	17.3	0.00082	0.00078	0.00101	0.00056
4	15.2	15.2	16.9	16.7	0.00067	0.00066	0.00095	0.00101
5	13.0	13.0	18.6	20.1	0.00101	0.00101	0.00079	0.00099
6	6.6	6.7	14.4	17.4	0.00072	0.00072	0.00018	0.00022

Reach	Channel Velocity			
	Existing Cond 2-year Flow	Prop Cond 2-year Flow	Existing Cond 100-year Flow	Prop Cond 100-year Flow
1	1.3	2.0	3.3	5.9
2	4.5	4.3	6.8	6.9
3	5.7	5.6	7.2	5.6
4	5.5	5.4	7.2	7.2
5	5.7	5.6	6.1	7.0
6	3.1	3.1	2.3	2.9

* Channel hydraulic depth
** Total energy slope
Note: Differences between the existing and proposed conditions for the 2-year peak discharges are likely artifacts in the model